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and

May the New Year

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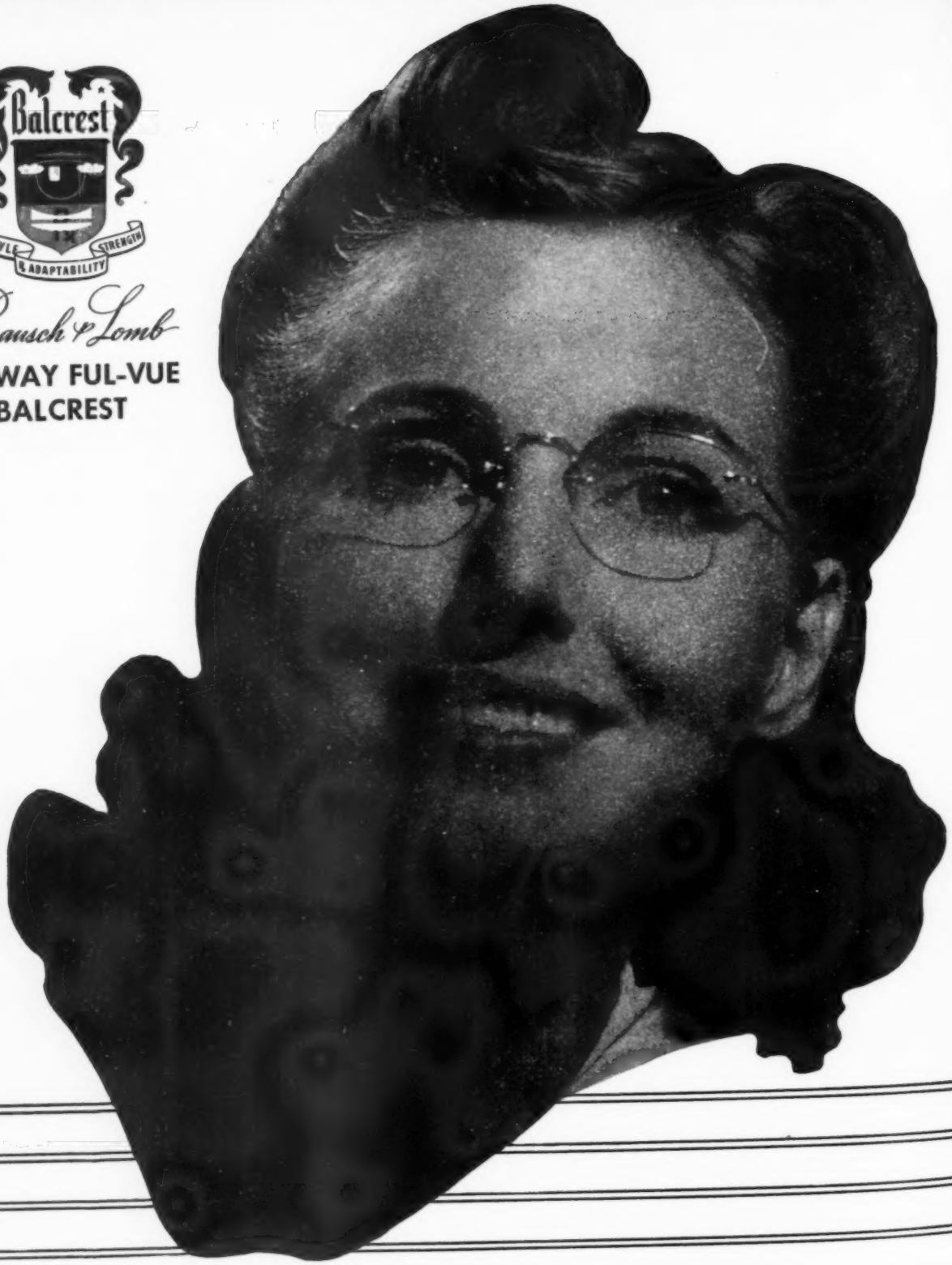

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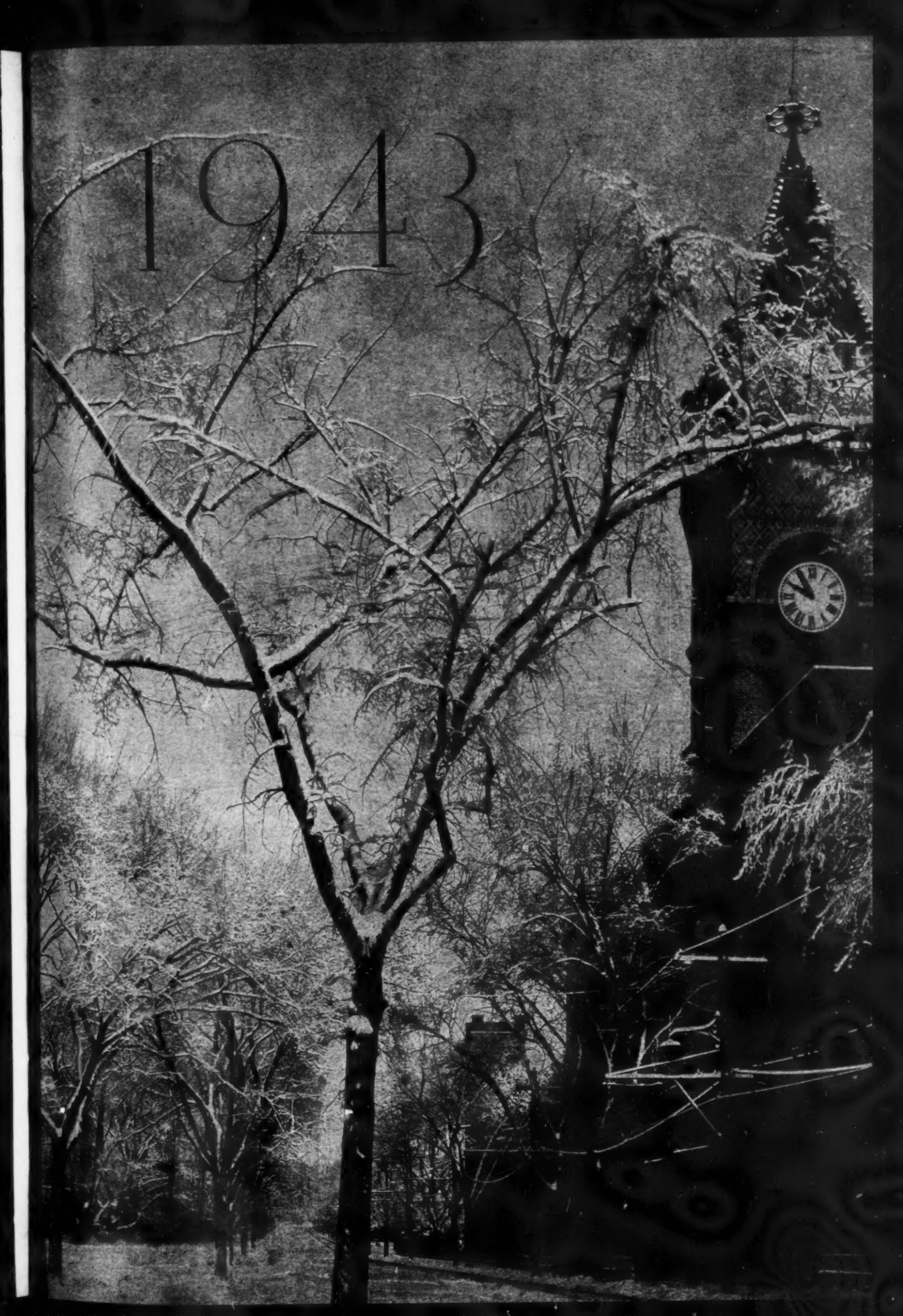
1943

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Vol. 19, No. 12 DECEMBER, 1942

ANISEIKONIA IN ROUTINE REFRACTION*

Harold M. Fisher, O.D.
New York, N. Y.

Much has been written during the past few years on the subject of aniseikonia. The greater part of this material consists of technical reports of research work conducted at the Dartmouth Eye Institute.[1] Most of this work deals with rather new concepts which are relatively difficult for us to interpret in the light of our everyday experiences in the practice of optometry. This has led to the widespread opinion that aniseikonia is one of the mysteries,—an esoteric subject beyond the reach of the average optometrist. Is is my attempt today to take some of the mystery out of this subject, bring it down to earth and show, if I may, some of its many practical applications to our routine optometric problems.

Perhaps the greatest barrier to a useful understanding of aniseikonia is the failure to understand exactly what is meant by the Dartmouth definition of aniseikonia. We all know that the literal meaning of the word aniseikonia is unequal images. Our familiarity with the laws of optical imagery has accustomed us to thinking of visual problems in terms of the retinal image. So it is not surprising that many of us have come to the false conclusion that the term aniseikonia refers to inequalities of the retinal images. This perfectly natural error has led to a great deal of misunderstanding of the subject of aniseikonia. The Dartmouth definition of aniseikonia is simply the difference in the relative size or shape of the *ocular* images in the two eyes. The term ocular images is the core of the definition and the cause of much misunderstanding. The ocular image is the image that is carried to the brain, the perceptual image, and distinctly not the dioptric or retinal image. It is not a physical entity and exists nowhere but in the mind. True, it is influenced by the size of the retinal image, but it is also

*An abridgment of the material presented before the American Academy of Optometry at Chicago, Illinois, December 9, 1941, for publication in the December, 1942, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

[1]A list of publications issued at the Dartmouth Eye Institute shows 67 papers as of January 1, 1941.

affected by anatomical factors within the retina and brain and by the psychological process of visual perception, and probably also is influenced by other sensations, auditory, kinesthetic, etc. This was the new thought contributed by Dartmouth, and from this new concept arose many implications regarding binocular space perception now being investigated. If we keep this definition in mind we will not fall into the unfortunate habit of thinking of aniseikonia solely in terms of unequal refraction. We will also realize that it may be possible that aniseikonia is not a fixed and innate characteristic of a pair of eyes, but may be subject to variations within the individual's ability to adapt his visual perception to his visual environment.

Now, how can such differences in the size of the ocular images be of interest to us in the daily practice of optometry? I have found that there are *four* common manifestations of aniseikonia. We should be prepared to recognize and cope with these conditions whenever we meet them, if we are to provide our patients with adequate optometric care.

Perhaps the most important of these manifestations of aniseikonia is the problem case, the patient who appears to have marked ocular complaints, yet shows no manifest uncorrected ocular anomaly that might account for these complaints. The complaints may vary from simple eye fatigue or pain on relatively short use of the eyes to severe pain, headaches, photophobia, nervousness and other referred symptoms. You will note that these complaints include those usually found in cases of accommodative fatigue as well as in cases of convergence insufficiency. There is nothing typical or pathognomic about these symptoms which would guide us to a differential diagnosis of aniseikonia, although it may be of some significance that the complaints are often associated with restricted or rapidly changing fixation, as in visual tasks involving critical seeing of fine details or where moving objects are being observed. No doubt some of these patients are neurotic and a few of them may be medical problems, but I know from my own experience that a great many of them, perhaps fifty per cent, are suffering from aniseikonia.[2]

Another group of cases in which aniseikonia may be a factor is the fusion problem case. Those of us who have done work with orthoptics are familiar with the cases which will progress just so far and no further. I am convinced that at least some of these cases are prevented from developing normal binocular single vision by differences in the relative size of the ocular images. I have seen a number of cases that improved markedly in this respect after correction of aniseikonia when orthoptics

and surgery had previously failed. I have seen several cases that spontaneously attained stereoscopic vision upon correction of aniseikonia. The measurement of aniseikonia should certainly be included in a complete study of every orthoptic case.

The third group of cases is familiar to all of us although there is no commonly accepted term to describe this group. Typical of this group is the patient who complains that he cannot wear the new glasses which have been recently prescribed because the world looks topsy-turvy through them. Not all patients are able to express themselves clearly in describing how things look through the glasses. Planes may actually appear tilted or slanted or displaced laterally but the patient may complain of dizziness or say that things look closer or farther away or smaller or larger. The essential fact is that there is a specific distortion of their space perception which is very likely caused by differences in the relative size of the ocular images introduced by the changes made in the refractive correction.

There is a fourth group of cases in which aniseikonia must be taken into account, though this hardly constitutes a separate type of case because it is frequently found in each of the three types of cases described above. This group of cases is the anisometropes. I hope that by mentioning this group I will not create confusion in your minds in connection with what I have said about the Dartmouth definition of aniseikonia. The fact remains that anisometropia may present a problem in aniseikonia, but not in every case. I hope that I will be able to clarify this point a little later on.

Thus we have seen that there are four problems involving aniseikonia which all of us are certain to meet in the everyday practice of optometry. They are,

1. Ocular discomfort and headaches of unexplained origin.
2. Fusion problems which do not respond to treatment.
3. Disturbances of space perception.
4. Anisometropia.

To explain exactly why these four problems involve aniseikonia would be a lengthy and technically involved task and is entirely beyond the scope of this paper. However, I would like to summarize in simple language a practical concept of the role of ocular image size differences in the process of binocular vision.

In normal binocular vision we make use of small differences in the

size of the ocular image to give us a three dimensional perception of space. That is to say, objects in space may normally present different angular sizes to the two eyes and it is by means of an interpretation of these differences that we obtain the perception that the object is where it is. When there is a difference in the size of the ocular images to begin with, there is a false perception of space, that is, a spatial interpretation of the size difference. Inasmuch as our visual perception of space must be reconciled with other perceptions and our experience, we are faced with two alternatives. We may compensate for the difference in ocular images, or we may learn to ignore our binocular perception of space. When we compensate, whether physically or mentally, (that is, as a mechanical response within the eye, or as a mental reorientation of perception) effort is expended. If this effort is greater than we can easily maintain, within physiological limits, it produces fatigue and results in the ocular complaints described above. If the effort is not expended there is false space perception with its attendant confusion. If this false perception persists there may result a loss of efficient binocular vision with suppression, loss of fusion and squint. Anisometropia in itself may not cause differences in the size of the ocular images, but a change in anisometropic correction is almost certain to introduce changes in aniseikonia.

As practicing optometrists we would like to do more than merely suspect the presence of aniseikonia in these problem cases. We would like to verify our suspicions and then proceed to measure and correct the defect. To do this work accurately requires precision methods of making ocular measurements. The equipment and lenses designed at Dartmouth do this work better than any other method yet devised.[3] What I will have to say is not to be interpreted as a substitute for these precise and proven methods. Yet a number of relatively simple methods have been proposed by various men from time to time. Since some of these methods might be adapted to our needs, I shall attempt to discuss them.

There is an urgent need for a reliable screening test to determine the presence or absence of aniseikonia. In the absence of such a test we must be guided by basic principles intelligently applied and interpreted. There are two such basic principles which we may apply in our office as avenues of approach to learn something about aniseikonia. The first of these is the principle of making direct comparison of the ocular images, the second is the principle of observing or studying anomalies of space perception.

Direct comparison of the ocular images may be accomplished in a

great variety of ways. The method now in use at Dartmouth has been described in several papers. It is essentially a direct comparison where polarized light is used to permit the two ocular images to be seen simultaneously but not fused while binocular single vision is maintained. Since this method involves a long and laborious procedure with rather elaborate and costly equipment, it is beyond the reach of many of us. There are other precise methods of making these measurements, but since they involve elaborate equipment, such as a haploscope, horopter device, tilting table, etc., they will not be discussed here. Of the simple methods of making direct comparisons of the ocular images without special equipment I would like to discuss four which have been most commonly mentioned as having value.

On first thought it would appear that the simplest and most obvious means of comparing the size of the ocular images would be to cover one eye and then the other, asking the patient to tell you which way some simple test objects appear larger. This method is of little or no value in connection with aniseikonia because it is not a comparison of the ocular images with which we are concerned. The eyes are functioning monocularly rather than binocularly under the conditions of this test. I have repeatedly measured patients who insisted that they saw larger with one particular eye and found with the eikonometer definite and unquestionable indications that no such difference existed. There are many factors which contribute to monocular interpretation of space relationships which are not operative in binocular space perception.* The only value that I can see in this particular type of observation is that if such a crude test indicates that there is a difference in size of the ocular images then the matter should be investigated by some more reliable method. If no difference is indicated by this type of test this does not necessarily indicate that aniseikonia is not present.

Another method which has been suggested by some who are apparently not aware of the precision required in this work is to use suitable charts in a Brewster type stereoscope. This method is of absolutely no value because the inaccuracies of the instrument may introduce size differences greater than those we are attempting to measure. A Wheatstone type stereoscope with a rigid chart support might be useful, but there is none on the market that I know of in an inexpensive form.

A prism stereoscope, such as a kratometer, might be used with

*Helmholtz discusses this point in the first section of Volume III of his Physiologic Optics.

suitable charts, but since this instrument is not widely used I would prefer to discuss another method which is very similar optically and which may prove to be of some value.

Vertical dissociation of the two eyes with prism base-up in front of one eye and base-down in front of the other offers a simple means of making gross comparisons of the ocular images and has the further advantage of being available to all of us who have a trial frame and prisms or a phoropter. The simplest form of this test is to use some small discreet test object such as a 20/200 E and ask the patient to compare the apparent relative size of the two images thus seen. The results of such a test applied this way are, however, often misleading because the perception of size is affected by kinesthetic clues associated with accommodation and convergence which may not be the same when fusion is present as when the eyes are dissociated. Normal discrimination for size is of the order of three to five per cent so the best we can hope to do with this sort of test is to estimate the relative size difference within these limits. It is conceivable that the use of specially designed charts with vertical dissociation would permit the measurement of aniseikonia to a degree of accuracy which would compare favorably with the mthods used at Dartmouth. However, even with such special charts the results are difficult to interpret unless the relative size of the ocular images can be varied by definite known amounts and the patient's observations compared with these size changes. One or two overall and meridional size lenses should be very helpful in this respect.

In applying such a test we must carefully guard against three sources of error. *Asymmetrical convergence* resulting from even a slight rotation of the head may cause indications of the size differences when in reality none is present. Differences in the *vertex distance* of the correction lenses will also introduce size differences particularly where the power of the correction is high. The *distortion* of the flat prisms used to create vertical diplopia may also introduce size differences which will affect our findings. The magnifying effect of a flat prism varies along its base apex line so that when the patient looks through these prisms above or below its center a size difference is introduced. This fault can be overcome by carefully centering the eyes in the phoropter. All three of these sources of error are minimized when the test is done at distance rather than at near. Where binocular vision is not present this test is essentially a monocular test and becomes practically useless because it is subject to the same factors which influence monocular comparison. In the border-

line case it is difficult to be certain that both eyes are actually functioning at the same time although there are some checks for this in the charts referred to above.

Anomalies of space perception can be detected in some cases by a very simple device. A large sheet of blotting paper, cardboard or building board without rectilinear pattern held in the patient's hands will give us some clues to his space perception. We merely ask the patient to stand holding the board at waist level and place it so that it appears perfectly level. Another variant of this test is to use a plain card in the reading card holder of your phoropter arm. If after several trials we find that there is a consistent tendency to tilt the board in one specific direction we may interpret this tilt in terms of disparities of the ocular images. Tilts to the right and left are the result of differences in the size of the ocular images. Tilts forward and back are due to the combined effect of head tilt, cyclotorsion, oblique size differences and oblique cylinders. The difficulty in interpreting these tilts arises from the fact that image disparities will not always produce a tilt, and any given tilt may be caused by any one of many different image disparities. In some cases the tilt will not become manifest due to highly developed monocular space perception which over-rules the false binocular space perception. The usefulness of this test is somewhat enhanced through the use of a few size lenses to create known size differences and suitable means of measuring the tilts produced by them. Such a device is the tilting table described in various papers from the Dartmouth Eye Institute.[4]

In general, tilts which are manifest by such tests or are described to us by the patient may be interpreted qualitatively according to the following table.

Plane seen level when placed	May be due to
Up in front	Crossed disparity of superior field, as in plus cylinders out at the top
Down in front	Uncrossed disparity in the superior field, as in plus cylinders in at the top
Up on the right	Right ocular image larger than the left horizontally or smaller vertically
Down on the right	Right ocular image smaller than the left horizontally or larger vertically

In interpreting the patients' descriptions of the tilts which they have

observed it should be remembered that their observations will be exactly opposite to their settings of a tilting plane so that it appears level. A simpler and possibly more useful interpretation of these tilting effects is as follows:

1. A tilt to the right or left definitely indicates that aniseikonia is present.
2. A tilt forward and back indicates that aniseikonia may be present.
3. No apparent tilt indicates that aniseikonia may not be present.

Thus we have some simple tests which may serve us in the refracting room to go a little beyond merely suspecting the presence of aniseikonia. In interpreting these tests it should be remembered that findings obtained at near may not apply to distant vision and findings obtained through trial lenses may not apply to spectacle lenses. My own clinical use of these methods has been sufficient to verify their validity but unfortuantely I have not yet accumulated sufficient data to give a reliable estimate of their accuracy. If these methods fail to indicate aniseikonia and the conviction still remains that aniseikonia may be present, the patient should be referred for examination with the eikonometer.

If, however, we have confirmed our suspicions as to the presence of aniseikonia, what can we do to devise a more satisfactory refractive correction without going to the tedious and expensive procedure of eikonometer measurements to prescribe an iseikonic correction? As I have said before, there is no adequate substitute for the eikonometer and eikonic lenses. There are, however, some points regarding the magnifying properties of ophthalmic lenses which may be applied to prescribing an ordinary refractive correction with the view to minimizing gross differences in the size of the ocular images such as might be detected by the methods described above.

The magnifying effect of an ophthalmic lens depends upon four factors, power, position, base curve, thickness.[5] These four factors are related in such a way as to suggest that there is a magnification due to the power of the lens and a magnification due to the shape of the lens which combine to give the magnification of the lens as a whole. This relationship may be expressed as follows :

$$M = Mp \times Ms$$

$$Mp = \frac{1}{1 - p\,V_0} \qquad MS = \frac{1}{1 - t/n\,D_1}$$

where,

M = Magnification
Mp = Power Magnification
Ms = Shape Magnification
V_0 = Vertex Power
p = Vertex distance, from back vertex of lens to first nodal point of the eye
D_1 = Dioptric power of the front surface of the spectacle lens
t = Center thickness of the spectacle lens
n = index of refraction of the spectacle lens

These formulæ are correct only for distant vision. For near vision there is a glass or distance factor which complicates matters considerably and introduces a variable additional amount of magnification.

It would be extremely difficult, if not impossible, to apply these formulae directly to the solution of a specific problem in aniseikonia. The practical method of designing iseikonic lenses is to work from tables or graphs derived from these formulae. This is the method employed by the American Optical Company in designing these lenses. Even if we were successful in applying these formulae in designing an iseikonic correction, we would still be faced with the extremely difficult task of grinding them to the specifications which we had established. The most that we can hope to accomplish is to minimize differences which we know exist in the size of the ocular images and to avoid creating aniseikonia by the nature of the refractive correction which we might be inclined to prescribe. This much can be accomplished by a sort of rule of thumb method if we know roughly how variations in the four factors will influence the magnification of our spectacle lens. Here follows four rules, one for each of the four factors.[6]

1. Increasing the dioptric power of the lens by one diopter will increase the magnifying power by about 1/10% for each millimeter of distance from the nodal point of the eye to the back vertex of the lens.

2. Increasing the distance of the lens from the cornea by one millimeter will increase the magnification by about 1/10% for each diopter of power.

3. Increasing the base curve by three diopters will increase the magnification by about 1/5% for each millimeter of thickness.

4. Increasing the center thickness of the lens by one millimeter will increase the magnification by about 1/5% for each three diopters of base curve.

Thus we can see that the effect of dioptric power on the magnifying power of the spectacle lens is considerable, being in the neighborhood of 2% per diopter for a lens worn at the average distance of around 20 millimeters from the nodal point of the eye. The effect of corneal distance on the magnification is proportional to the dioptric power of the lens being slight for low corrections but becoming quite significant for corrections over 10.00 diopters plus or minus. The effect of base curve is negligible for minus lenses which are usually very thin but may become quite significant for the higher plus lenses where the thickness is considerable. The effect of thickness is zero for flat lenses but becomes appreciable for the deeper curved toric and corrected curve lenses.

How can we make use of these rules in the everyday practice of optometry? Here follows my recommendations as how best to handle each of the four types of case which I have described earlier in this paper. Let us assume that you have first questioned the patient closely as to their symptoms and have completed your refraction. Your history and findings have led you to suspect the presence of aniseikonia and you have studied the case further by means of the tests which I have discussed. It is necessary to proceed somewhat differently in each of the four types of case.

In the case who complains of ocular discomfort for which you can find no apparent cause ,the screening test will be of little use and nothing whatsoever can be accomplished by the crude methods which I have described. It is indeed unfortunate that in this largest and perhaps most important group of all, where the screening test is most needed, little can be done to confirm our suspicions as to the presence of aniseikonia without resorting to the precise methods which have been devised at Dartmouth. The reason why this is so should be fairly obvious when we remember that the reason these patients suffer is because they compensate for their size difference. In so doing their aniseikonia becomes latent in a similar sense to latent hyperopia. When the aniseikonia is latent there is little if any manifest size difference and either of our screening methods falls down. The best thing to do in this type of case is to refer them for eikonometer examination. If this is not possible, then we can at least tell the patient what our suspicions are and explain to them that they must not expect too much from whatever refractive changes we advise.

In the fusion problem case fusion may be absent or at least poorly developed so that the tilting test is of little or no value. However, since

the size differences which could cause fusion problems are apt to be high —of the order of four per cent or more—the comparison test may be helpful. If very definite and consistent responses indicate a certain type of size difference then the best course is to refer the patient for accurate measurement with the view to prescribing iseikonic glasses. I would not advise any of you to attempt to correct aniseikonia in this type of case, although it is conceivably possible if the nature and magnitude of the size difference and the type of refractive correction are favorable. If it is not possible to have the aniseikonia corrected properly, then the best that can be done is to modify the power of the refractive correction in the direction which will tend to minimize the size difference. This is at least a step further than routine refractive procedures will take us.

The patients who complain of disturbances of space perception are the group for which the methods I have proposed offer the most promise. Since the tilt is manifest to the patient so strongly that it constitutes a major complaint it is readily elicited by the tilting test. It is a simple matter to empirically vary the power and axis of sphere and cylinder to minimize the tilt. In so doing, we are almost certain to reduce visual acuity, and we must be careful that we do not introduce so radical a change into the refractive correction that it might produce more annoyance than the complaint we are attempting to alleviate. We may anticipate this sort of complaint and possibly prevent it in the first place by not giving our full finding in cases who have worn grossly inadequate previous glasses or none at all. A further precaution is to attempt this sort of modification of the correction only after the patient has been given a reasonable opportunity to become accustomed to his new lenses. In handling these cases we must try to strike a happy balance between three considerations, visual acuity, tilt, and comfort.

Anisometropia can not be considered as a separate group of patients because it is often found with any of the three conditions discussed above. However, since anisometropia is so frequently thought of in connection with aniseikonia, it deserves special mention. I hope I have made it clear by now that aniseikonia is not necessarily associated with anisometropia. Aniseikonia is frequently found when there is no difference in refraction and conversely it is often found that there is no aniseikonia in cases of anisometropia. I have even seen some cases where the aniseikonia was actually in the opposite direction to the anisometropia. So first of all don't start out with the thought that you must give the patient a pair of correction lenses which have equal magnifying power if

you are to give them comfort. We should be guided by the patient's symptoms in applying a screening test as discussed above. If there are no distressing symptoms then there is no particular reason to consider aniseikonia in connection with anisometropia. However, when the patient has never worn a refractive correction and we find a marked degree of anisometropia with normal corrected vision in each eye, then beware of trouble. The important thing to bear in mind in correcting anisometropia is to avoid making great changes in the difference between the two lenses. It is very good practice to work up to a full correction through several intermediate changes rather than to prescribe a full correction at the start and expect it to be worn with comfort. The old-timers had some good common-sense rules for this sort of thing and perhaps the reason why these rules worked out was that they took aniseikonia into account without knowing it. Here are the rules I have in mind,

Never attempt to correct anisometropia of over 1 to 1½ diopters.

Always undercorrect high astigmatism, especially at oblique axes.

Expect trouble from astigmatic corrections at opposite axes.

To these we may add a new rule which is to avoid making changes in the refractive correction which will introduce size differences of over one or two per cent, depending upon visual acuity—the better the visual acuity, the less difference will be tolerated.

Now to summarize: I have discussed four considerations which should lead you to suspect aniseikonia; unexplained ocular discomfort, fusion problems, space distortion and anisometropia. I have described tests which may be of use to you in diagnosing these cases. I have given some information about the magnifying properties of ophthalmic lenses. And an attempt has been made to show how this information may be applied in an attempt toward a solution of some of your puzzling cases. In presenting this material I have tried to make clear its very limited application and have emphasized the fact that it is not offered as a substitute for the eikonometer and eikonic lenses. I hope that I have provided you with a new procedure to apply in your refraction room which will help you to practice better optometry. May I wish you all good luck in your attempts to apply this knowledge, and venture to hope that a little knowledge will not prove a dangerous thing.

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NEW YORK CITY

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QUANTITATIVE RELATIONS BETWEEN LIGHT AND VISIBILITY*

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It has been adequately demonstrated that the effectiveness of light, as an aid to seeing, cannot be evaluated quantitatively by mere introspective appraisals of the visual situation.[1] Measurements are needed; and the fact that light is the only universally applicable means for increasing visibility augments the significance of such measurements. Since the most fundamental objective of light and lighting is to promote visibility, the present discussion and data are restricted to this aspect of the subject. However, it should be recognized that the criterion of visibility is not necessarily adequate for revealing all of the complex psychophysiological effects of light upon the human seeing-machine. It is also obvious that data relating to illumination and visibility should be considered in conjunction with the visual abilities and limitations of the individual.

There are at least four fundamental variables of the visual stimulus which may be controlled to augment visibility and which must be considered in appraising conditions for seeing. They are size, contrast, brightness and time—and they are complexly entwined. If an object is visible, it is due to the fact that each of these variables exceeds a certain threshold value.[2] Hence the degree of supra-threshold visibility is assumed to be proportional to the extent to which a given factor, or any or all factors, exceeds the threshold value or values.[3] In brief, these four visual factors comprise the external physical basis of visibility. However, their ultimate influence on seeing is modified by a chain of physical, physiological and psychological variables leading from stimulus to sensation and to response.

The complementary relationships between these fundamental visual factors are indicated in Fig. 1. The solid-line curve represents the border-

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line between visible and invisible objects when the brightness of the background is 100 footlamberts.* It will be noted that small objects must have high contrast to be recognized in detail. On the other hand, objects of low contrast must be relatively large in size in order to be visible. In both situations, visibility is increased by higher brightness-levels. It will be evident that the usual clinical measurements of visual acuity could be plotted along the abscissa of 100 per cent contrast; and that nearly a two-fold increase in acuity may be obtained by increasing the brightness from 1 footlambert to 100 footlamberts. Thus the relationships of Fig. 1 provide a physical basis for estimating the relative visibility of various dissimilar objects or tasks, as well as providing a basis for determining the effectiveness of light as an aid to seeing.

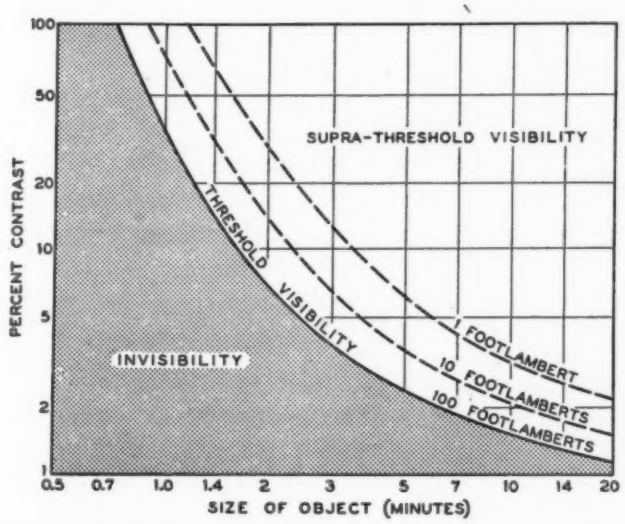

Fig. 1. Threshold relationship between contrast and size for three levels of brightness. The solid-line curve indicates the border between invisibility and supra-threshold visibility for a brightness of 100 footlamberts. The broken-line curves represent similar borders for brightnesses of 100 footlamberts and 1 footlambert, respectively.

It will be noted from Fig. 1 that the borderline between visibility and invisibility shifts upwards as the brightness-level is decreased. In

**Footlambert*: A unit of brightness, equal to the uniform brightness of a perfectly diffusing and reflecting surface illuminated to 1 footcandle. Therefore, the brightness in footlamberts equals the illumination in footcandles multiplied by the reflection-factor.

Footcandle: A unit of illumination. It is the illumination upon a surface placed at right angles to the light rays at a distance of one foot from a light-source of 1 candlepower.

other words, the world of invisibility is increased and the world of visibility is decreased. Similar unfavorable shifts occur when a glaring light-source is introduced into the field of view.[4] Obviously, defective vision, distractions, lack of attention, and other unfavorable factors also shift the curves of Fig. 1 upward and lower visibility since the curves were obtained under otherwise favorable conditions for observation. Perhaps the outstandingly important characteristic of these relationships is that a rather large deficiency in one visual variable may be offset by an augmentation of one or more of the remaining variables.

Inasmuch as contrast is a very important and generally neglected factor in seeing, it should be understood, in the case of a perfectly black object on a perfectly white background, the contrast is 100 per cent. It is computed by dividing the difference in brightness by the brightness of the brighter of the two and multiplying by 100. For example, if the paper and ink on this page diffusely reflect respectively 80 and 4 per cent of the incident light, the per cent contrast of any letter with its background is 80 minus 4 divided by 80 and multiplied by 100. The result is 95 per cent contrast. Excepting in reading material and certain tasks in offices, many visual tasks commonly encountered exhibit rather low contrasts. These require much higher levels of illumination for the same degree of visibility and ease of seeing than tasks

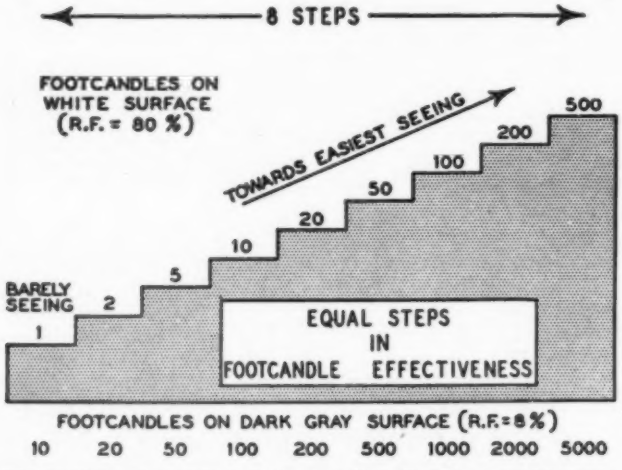

Fig. 2. Illustrating the scale of footcandle effectiveness. Numerous and diverse researches have established the fact that the illumination (footcandles) must be approximately doubled to produce equal and significant improvements in seeing. Obviously, the reflectance of the illuminated surface must be considered in specifying recommended levels of illumination. For example, a surface having a reflectance of 80 per cent and illuminated with 10 footcandles will be equal in brightness to a surface having a reflectance of 8 per cent and illuminated with 100 footcandles.

providing relatively high contrasts even though the size of the details may be approximately the same. Obviously, the contrast between an object and its background is also reduced by refractive errors, by scattered light within the eye, by cloudy media, etc.

It will be noted from Fig. 1 that the brightness (or illumination) must be increased in geometrical steps to obtain arithmetical increases in visibility. In other words, the footlambert as a unit of brightness diminishes in effectiveness as the brightness-level is increased. Similarly, a minute visual angle as a unit decreases in effectiveness as the size of the object of regard is increased, as will be evident from a study of Fig. 7. This characteristic of size, as a variable of the visual stimulus, is recognized in the design of charts for testing visual acuity. Similar relationships are also encountered in other realms of sensory physiology. For example, it has been shown that certain psychophysiological effects of more or less prolonged seeing also vary arithmetically as the brightness-level varies in geometrical ratio over a rather wide range.[5] This Fechnerian relationship is of primary importance in appraising the

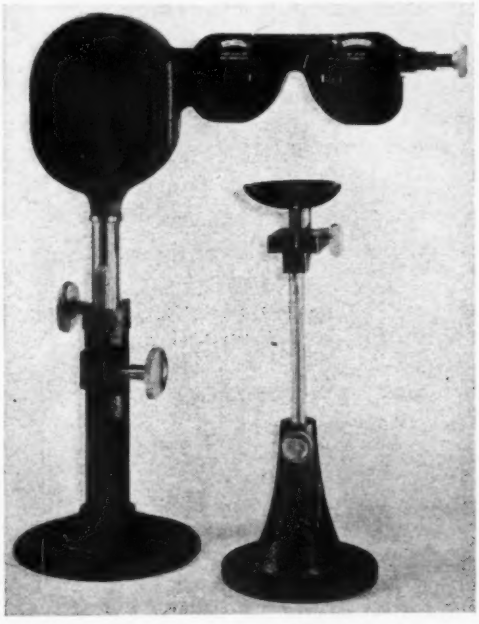

Fig. 3. Laboratory model of Luckiesh-Moss Visibility Meter. It combines the Visibility Meter proper with auxiliary apparatus to facilitate use of the meter. This apparatus, with suitable test-object and convergence target provides a precise means for determining the refractive state of the human eye. (Fig. 7.)

actual effectiveness of different levels of illumination; and Fig. 2 is a graphic illustration of it. It will be noted that equal steps in footcandle effectiveness result from approximately two-fold increases in illumination. In general, these footcandle steps are about the smallest ones which will produce obvious and significant improvements in seeing.[1] This fact should be recognized by those concerned with footcandle recommendations.

In applying these fundamental principles to a wide variety of practical visual problems, it is often necessary to determine empirically the relationships between illumination and visibility for specific objects, tasks and degrees of ocular efficiency. For this purpose, the authors have devised a visibility meter, one form of which is shown in Fig. 3. The principles upon which this instrument is based, its construction, calibration and use are described elsewhere.[6] All of the data presented in the following discussion were obtained with this meter.

Visibility of Tasks: If it is assumed, merely as a basis for comparison, that an illumination of 10 footcandles on 8-point type provides a reasonable standard of visibility, the data of Fig. 4 indicate the footcandles required on a variety of common tasks to attain this standard of visibility. For example, it will be noted that about 700 footcandles would be required in the case of precision die making, whereas levels between 30 and 50 footcandles would produce the same degree of visibility in the case of many clerical tasks. Although any standard of visibility may be assumed arbitrarily as a base, it should be recognized that the *relative* amounts of light required by different tasks are fixed, and that these relative values are determinable with considerable exactness.

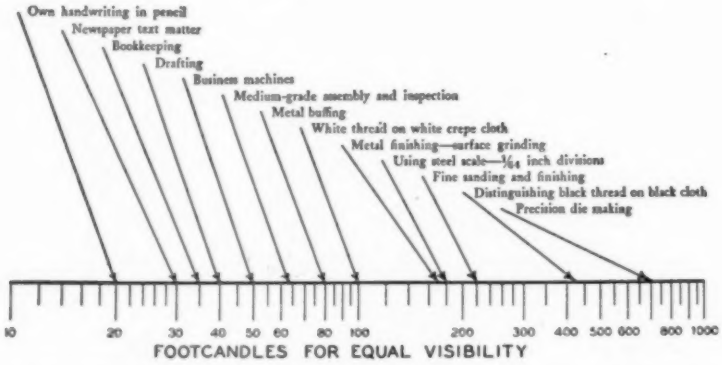

Fig. 4. Indicating the illumination required on various visual tasks in order that each be as visible as 8-point type under a uniform illumination of 10 footcandles.

The data of Fig. 4 emphasize the fact that the levels of illumination producing equal visibility among many common tasks differ enormously. This fact should be recognized when considering footcandle recommendations. Furthermore, it is a reasonably safe assumption that while differences in vision among a given group of workers are usually recognized and emphasized, it is not unusual to underestimate or even to ignore the wide differences in visibility among the visual tasks to be performed.

Many tasks performed in schools and in offices differ in visibility about as widely as those given in Fig. 4. For example, the data of Fig. 5 indicate the relative visibility of the lettering in a variety of so-called comic books.[7] They also reveal the severity of the visual tasks in reading some of these books. For purposes of appraising these tasks, two groups of specimens, designated as *average* and *superior*, were subjected to detailed study and measurements. Each group consisted of 24 specimens, carefully selected to be truly representative. The *average* group was selected from a large number of run-of-the-mill comic books. Some of these specimens represented approximately the largest and best lettering in these books. However, most of the specimens in this group were selected to represent the more severe visual tasks, although by no means were the selections predominantly the obviously worst ones. The *superior* group was selected from three comic books whose publisher had given particular attention to increasing the quality of lettering, paper and printing.

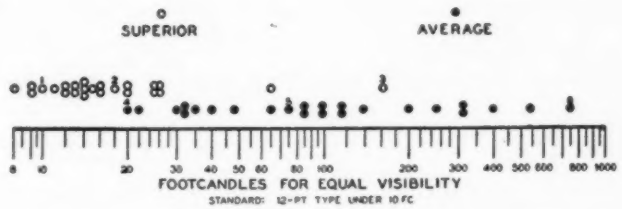
SUPERIOR
AVERAGE
8 10 20 30 40 50 60 80 100 200 300 400 500 600 800 1000
FOOTCANDLES FOR EQUAL VISIBILITY
STANDARD: 12-PT TYPE UNDER 10 FC

Fig. 5. The footcandle scale indicates the levels of illumination required on various comic books in order that the lettering be as visible as 12-point Bodoni Book type under an illumination of 10 footcandles. The solid and open circles refer to books of average and superior quality, respectively. A few of these specimens may be described as follows with respect to lettering and background. Superior: (1) large lettering on white, (2) large lettering on yellow, (3) medium lettering on blue. Average: (4) medium lettering on white, (5) medium lettering on red, (6) small poor lettering on dark green.

It will be noted from Fig. 5 that the least visible lettering required an illumination 100 times greater than the most visible lettering in order

to be equivalent to the latter in visibilty. Obviously, quantitative measurements such as these should be effective in establishing more favorable visual conditions for performing the critical task of reading.[8] These data are all the more significant when the fact is considered that these books are read by children whose visual mechanisms and visual habits are still in a more or less formative stage.

Vision and Visibility. In view of the varied uses of the L-M visibility meter in measuring the visibilities of objects and tasks under radically different conditions, it follows that it would also be useful in determining the degree of visibility afforded, by a given combination of visual condition, to those possessing subnormal vision. For example, sight-saving classes present an appealing opportunity for increasing visibility and ease in seeing through (1) the correction of ocular deficiencies, (2) the provision of suitable reading materials, (3) the provision of adequate illumination and proper lighting, and (4) the regulation of visual tasks and their duration in accordance with the visual ability of the subject. These are the controllable phases of seeing and, in this case, the restrictions upon complete control which are often imposed by so-called practical considerations are reduced to a minimum. The present discussion pertains largely to the second and third controllable phases, insofar as it is possible to separate these intimately interrelated factors.

Since reading constitutes the major critical visual task in the classroom, the discussion is restricted to this task. The textbooks used in sight-saving classes are commonly printed in 18-point or 24-point type and upon non-glossy white paper, although the latter is not invariably used. However, there is no optical reason why white paper should not

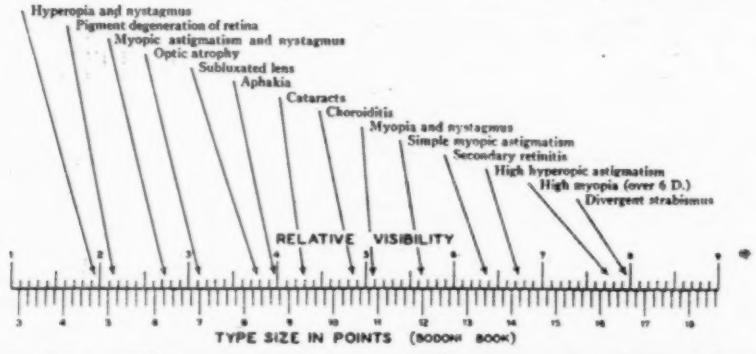

Fig. 6. The visibility of 24-point type, as viewed by various sight-saving pupils, as compared with the visibility of different sizes of type as measured by adult subjects possessing normal vision. The level of illumination was 10 footcandles in all cases.

always be used.[9] Thus the physical characteristics of the important visual tasks performed by the pupils are describable and hence subject to quantitative analysis. However, it appears that there is no general agreement as to the size of type best suited to the needs of the sight-saving pupils. Furthermore, the problem of optimum type-size is often complicated by economic considerations. For example, the cost of books printed in 24-point type is said to be about three times as great as that of books printed in 18-point type. However, such a difference in cost should become insignificant when it is compared with the difference in ease of seeing and efficiency in reading in the two typographical materials and with the total cost of educating these pupils. Obviously, ambiguity in evaluating the relative advantages of the two materials may over-emphasize the importance of the difference in cost.

The data of Fig. 6 indicate the visibility of 24-point type printed in black ink on a good grade of white book paper under a uniform and diffuse illumination of 10 footcandles as measured by sight-saving pupils possessing the indicated ocular defects.[10] These data were obtained with the L-M Visibility Meter and with the same technique used in obtaining the data presented in Fig. 4. In order to aid in interpreting these values, they are compared directly with the visibility of various sizes of type as measured by adult subjects possessing normal vision under an illumination of 10 footcandles. For example, it will be noted that in the case of hyperopia and nystagmus, the visibility of 24-point type is no greater than that of 5-point type in the case of normal vision. Since 24-point type is about as large as is practicable, from both economic and perceptual viewpoints, it is obvious that further assistance to these visually handicapped subjects must be obtained by other means.

In the same investigation, it was shown that the superiority of 24-point type over 18-point type in visibility could be offset, for the average case, by doubling the illumination on the 18-point type. As a lighting problem, a doubling of the levels of illumination now in general use does not involve either technical or economic difficulties. In fact, much greater increases may readily be obtained by proper considerations of light control and distribution. Some of the recent lighting installations in sight-saving classrooms provide a uniform, diffused and automatically regulated illumination of about 30 to 40 footcandles.

Visibility and Ametropia. The influences of various refractive errors upon visibility, assuming that such errors are not compensated by relative accommodation, are shown in Fig. 7. These data were obtained by an adult emmetropic subject for a fixation distance of 40 cm. The

test-object, in all cases, was a single black bar upon a white field illuminated to the brightnesses from 2.5 to 40 footlamberts. The scale of visibility, in this case, is the same as that shown in Fig. 5. Its derivation and significance are described in detail elsewhere.[11] For present purposes, it is sufficient to state that this scale is as appropriate for revealing the effects of refractive errors (Fig. 7) as it is for revealing the effects of pathological defects of the eyes (Fig. 5) or for revealing the influence of illumination on visibility (Fig. 4). Thus this scale and the technique for obtaining these values are useful in correlating data obtained in various sciences dealing with human vision.

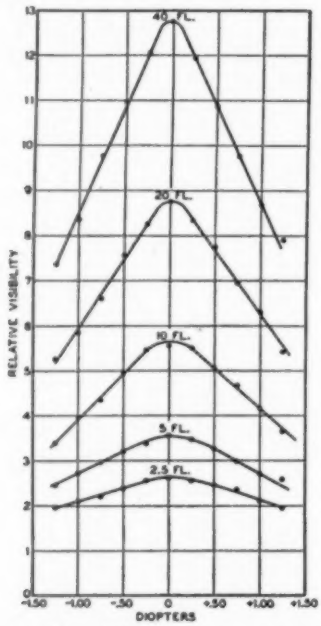

Fig. 7. The reduction in the visibility of a given test-object, located 40 cm. from the eyes, due to the addition of various plus and minus lenses to normal eyes, as determined for various brightness-levels. In obtaining these data, relative accommodation to the various trial lenses was avoided.[12]

It will be noted from Fig. 7 that large relative increases in visibility (compare with Fig. 6) are obtained from rather moderate increases in brightness. These data also show that the relative influence of brightness on visibility is about the same in ametropia as in emmetropia, at least within the ranges of the variables studied. This characteristic is an important one since it reveals the potential contributions of higher levels of illumination to those possessing refractive anomalies which are not completely correctable with ordinary ophthalmic lenses.

The data of Fig. 7 also indicate that the addition of equal amounts of plus and minus power, respectively, to normal eyes results in substantially equal losses in visibility in the case of near-vision.[11] In other words, these data fail to reveal any evidence of a lag of accommodation in near-vision for so-called emmetropic eyes.[12] It will also be noted that the loss in visibility due to a given uncorrected refractive error apparently increases as the brightness-level is increased. This artifact is attributable to the decreasing significance of the unit of visibility, as the test-object becomes more visible under higher levels of illumination. Obviously, these relationships between visibility, refraction and illumination are also appropriate for interpreting clinical visual acuity data since the values of relative visibility are directly related to the visual acuity designations of the Snellen Chart.

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THE ACADEMY AND THE PROFESSIONAL ADVANCEMENT PROGRAM

The Professional Advancement Program recently adopted by the American Optometric Association contains four major objectives. These are (1) increased membership in the association, (2) enlarged enrollment in optometric undergraduate schools, (3) improved professional and ethical standards for the men now in practice, and (4) the development of a co-ordinated national public relations program on a statewide basis.

Under the direction of Dr. Ewing Adams, president of the American Optometric Association, progress will be made in achieving these objectives. The present plans are good and are worthy of study and

careful attention. Optometrists everywhere should lend their support to the development of these objectives as the immediate future of the profession is intimately connected with their being carried forward to a full and successful conclusion.

The American Academy of Optometry and its local affiliates may be of assistance in the successful carrying out of these objectives. While in a great measure these A. O. A. projects are entirely outside the scope of the Academy, that portion having to do with professional practice and ethical standards is well within the confines of interest of these organizations and constitute matters on which the Academy may speak with authority.

For more than twenty years the American Academy of Optometry has studied with considerable care the requirements of both optometrists and patients in the field of professional optometric practice. During this period it has also required of its entire membership a very high type of professional practice and ethical conduct as part of its membership requirements. This has naturally built up a large and sound back-log of factual experience on the subject which is now available to the A. O. A. and which also we are sure will prove to be of great value inasmuch as now our national association is itself emphasizing in its Professional Advancement Program these same requirements of proper optometric practice.

For years all optometrists have more-or-less conceded that high optometric ethical standards and professional practice were excellent ideas, and also were, to be sure, from most standpoints, very fine ideals indeed. Yet some practitioners, who had never tried to live up to them also insisted that from the business side of the practice of optometry, that these ideals were impractical and too costly to put into use.

The Academy and its growing membership indicate that perhaps these latter people have failed to fully study the question and the fact that most present optometric leaders are members of the Academy and practice in full accordance with the highest ethical and professional standards of optometry indicates also that it not only can be done but also that it is being done with considerable profit, as these leaders for the greater part enjoy large practices.

The Academy has for years set the standard of optometric practice. This standard has been high, yet each year sees more and more optometrists living up to every and all requirement. Progress is being

made in this particular, and the experience of the Academy of the past are now at the disposal of the A. O. A. in enabling our national association to achieve the present goals set forth in the Professional Advancement Program. The A. O. A. is to be congratulated on this new development which will add much towards the upbuilding of our profession.

Carel C. Koch.

SPECIAL REPORTS

A. O. A. PROFESSIONAL ADVANCEMENT PROGRAM

E. LeRoy Ryer, Opt. D., F. A. A. O.
National Director General

The future of every optometrist hangs in the balance.

Weak numerically, and therefore politically, the A. O. A. has not been able to obtain at Washington a fair consideration of Optometry's claims to usefulness.

Fundamentally strong, these claims deserve fair consideration, in the public interest.

Among 135,000,000 people of our cultural standing there exists an enormous number handicapped directly and indirectly by faulty seeing conditions which optometric treatment alone can counteract.

A relatively small portion of these seeing deficiencies is receiving proper attention at the present time.

Not even all the obviously handicapped are cared for, let alone those handicapped by ocular strains which have not yet manifested themselves as inadequate seeing or poor sight.

Seeing deficiencies, manifest and latent, handicap students, at an ever-increasing rate, from kindergarten through college.

Seeing deficiencies, manifest and latent, make terrible inroads on efficiency in business, industry, and profession.

In a word, seeing deficiencies, manifest and latent, exact a vicious, if insidious, toll in every walk of life—resulting in inefficiency where efficiency could exist; unhappiness where happiness could exist; debility where virility could exist.

Should the Federal Government, solicitous for the general welfare, permit a politico-medical group to deny the public the services of 15,000 optometrists highly trained as specialists in uncovering and remedying these undermining seeing deficiencies?

The legislatures of the forty-eight states, and the District of Columbia, have recognized the profession of Optometry exactly as they have recognized the professions of dentistry and medicine. Former Chief Justice Hughes, when Governor of New York, approved the bill recognizing Optometry as a profession. Supreme Court Justice Roberts fought, and won, against medicine's, Optometry's case in Pennsylvania. And so on in every State in the Union.

Yet a section of the O. P. A. and other administrative agencies have the effrontery to say that Optometry is not a profession; that optometric services are not essential; that optometric services are merely incidental to selling glasses.

And too, Optometry is denied recognition in many departments of Government, where, optometric services, insuring better seeing, are of paramount importance.

A section of organized medicine aims to wipe out Optometry. Every optometrist has experienced the effects of this aim and Organized Optometry has been most unfairly attacked by READERS' DIGEST, P.M., and N. Y. WORLD-TELEGRAM, who have been used, unwittingly let it be hoped, as tools by certain clever politico-medical propagandists.

Came the awakening!

Optometry feels the finger tightening on her throat.

Optometry is gasping for breath and those who put her where she is turn to the A. O. A. and shout loudest for help.

Who put her where she is? Those who would not practice along recognized professional lines.

Are they ready, at last, to repent and reform? Who knows? And what difference does it make if Optometry be eliminated? It was an academic question before, now it is a question of life or death.

Now we face a real emergency and instead of using that term lightly, as formerly it has been used, let it be driven home in its real sense—and acted upon in that sense, viz:

An emergency is clearly defined as a sudden condition calling for immediate action.

And Optometry now faces a real emergency. Not one that can wait for that slow development so long cherished. Not one that can wait for politico-medicine to be appeased (as if that were possible). Not one that can wait for bureaucrats to be re-educated. Not one that can wait for the optometrist to get out of the store that is at the bottom of Optometry's trouble.

No, this is a real emergency calling for immediate action.

What action?

Action that will give us effective representation.

Action that will give the A. O. A. a membership of 12,000 or 15,000 in place of its present 6,000.

There are many other needs for action. Action must be taken to insure greatly increased enrollment of students. Action must be taken to establish ethics worthy of true recognition. Action must be taken to insure fairer public relations. And those actions will be taken.

But the immediate, the most pressing, need is for increased membership in the A. O. A.

If with full membership, twelve to fifteen thousand strong, the A. O. A. cannot obtain recognition for Optometry, then Optometry as a profession faces elimination.

Having practiced as I have practiced, having stood and worked for what I have advocated, I feel that if I can lay everything else aside in this emergency, any man can.

I see nothing that comes anywhere near holding as much promise for Optometry's survival as the A. O. A. Professional Advancement Program.

Unless you have a worthy alternative I ask you to support this one in this emergency.

Secure Optometry's existence in order that we may have the chance to modify her ethics and her economics, which are in such sad need of modification. But secure her existence without further delay or run a grave risk of total elimination.

Ask yourself, as I have asked myself, what have I to propose if the Professional Advancement Program fails?

My conclusion is that if this fails we will not have time even to propose, let alone to organize and carry out, any other program.

The emergency is real, the Program is the only action that can

be taken immediately to meet the sudden condition, and the first step in that action is to lay aside all secondary disagreements and considerations and form an effective A. O. A., which means an A. O. A. with a membership of at least 12,000—if not 15,000.

If each of the present 6,000 members of the A. O. A. would bring in just one new member, the 12,000 sought would be obtained. Instead, we ask one member to bring in 9,000. The member to whom this arduous task has been assigned is Dr. Joseph Seifert, National Director of the Office of Organizational Advancement.

Help him. See to it that the 9,000 who have been riding free pay their way—they benefit equally from all A. O. A. activities.

TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

by J. Fred Andreae, Secretary

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

A MESSAGE FROM PRESIDENT WHEELOCK

A year has passed . . .

We remember, so well, the events taking place just a year ago. The month of December and especially the last one will always be printed firmly in our minds, December the 7th, Sunday. Our annual meeting in full swing in Chicago. We, relaxed in comfortable seats in a warm room, listening to a lecture, perfectly satisfied with life; then out of the sky came the headlines that caused the hush and a stillness—WE WERE AT WAR. One does not give in easily to the realization of the fact that it had happened to us.

Assembled as we were, grouped with thoughts in common to us all, more determined than ever to go on with our traditional American way of living.

During this season of the year, we would ordinarily review the events that have occurred since the last holiday season. However, if we are to keep pace with changing times and a changing world, we must not look back but must look forward with confidence and optimism. A large number of our profession are serving with the armed forces on

the many fighting fronts. The remainder of our profession are serving on the home front.

To those with the armed forces, we salute you . . .

To those at home, may we bring to your minds an important duty you must perform.

No one can forecast the end of the war but we do know that every passing hour brings the end nearer, and also brings nearer that time when we will welcome our fellow optometrists home. The majority of these men are young and when they do return from battle, conditions in their communities will have changed and the contacts they had previously established will be gone. They will need counsel and help and advice to enable them to again establish themselves. It remains for the members of the American Academy of Optometry to maintain the ideals for which the Academy stands and to serve as guiding lights for our returning victorious heroes.

As president of the American Academy of Optometry, I send best wishes for the Christmas Season and know that from the tumult and strife will come a better world in which to live.

Arthur P. Wheelock.

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This is an index covering all of the departments of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY. The letters used to explain in which department the material indexed appears are as follows: (OP), Original paper; (CC), Current Comments by Carel C. Koch; (E), Editorial; (T), Transactions of the Academy by J. Fred Andreae; (PI), Procedure and Instrumentation by G. L. DuPlessis; (OJ), Organization and Jurisprudence by Clarence W. Morris; (SR), Special Reports; (C), Correspondence; (Ab), Abstracts; (I), Inquiry and Explanatory Notes; and (BN), Book Notices.

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